

THE AVAILABILITY OF POTASSIUM IN ORTHOCLASE FOR PLANT NUTRITION



DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree
of Doctor of Philosophy in the Graduate School of
the Ohio State University

By

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The Ohio State University
1922



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UNIVERSITY OF CALIFORNIA

Dissertation

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AVAILABILITY OF POTASSIUM IN ORTHOCLASE FOR PLANT NUTRITION^{1,2}

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Received for publication July 7, 1922

INTRODUCTION

Chemical analyses show that potassium is always present in soils and, with the exception of peats, mucks, and light soils, in relatively large quantities.

Experiments conducted at the Pennsylvania Experiment Station by Frear and Erb (24) indicate that, in some soils at least, potassium is not only present in considerable quantities but is available to such a degree as to render fertilization with this element unnecessary. In other soils, however, according to DeTurk (21) the potassium normally present is held in such a form that very little is readily available for the use of farm crops. Such soils respond readily to the use of soluble potassium fertilizers, and as a matter of fact, such applications seem to be necessary for maximum crop production.

While the greater percentage of the soil potassium is held in the form of relatively insoluble silicates such as biotite, muscovite, orthoclase, microcline, etc. and their decomposition products, a part is derived from plant residues. If it were not for the latter source, plants requiring large quantities of potassium probably could not reach full maturity owing to the limited amount of the element going into solution from the native minerals. An experiment by Hopkins and Aumer (27) is of interest in this connection. They found that soil freed of acid-soluble potassium would not, at first, support the growth of plants. As all other nutrient materials were supplied to this particular soil, the plants utilized the potassium of the seed, but death occurred soon afterward because the plants were unable to obtain further supplies of this element from the soil. It was found, however, that if these plants were not removed but incorporated with the soil and the process repeated several times, normal growth could be obtained eventually.

The above experiment does not signify, however, that plants are not capable of utilizing potassium directly from the minerals themselves. Lichens readily obtain a foothold on the most resistant potassium-bearing rocks, such as granites. Rocks of this nature compare, in a measure, to the soil freed of available potassium as used in the experiment already mentioned.

¹ The author takes great pleasure in thanking Dr. Firman E. Bear for the many helpful suggestions which he so kindly gave him in the pursuance of this work.

² A thesis submitted to the faculty of the Graduate School of the Ohio State University, in partial fulfillment of the requirements for the degree of Doctor of Philosophy, and published as Contribution No. 2 from the laboratories in Agricultural Chemistry, Pennsylvania Experiment Station.

OBJECT OF THESE INVESTIGATIONS

In view of the fact that most soils contain enough potassium to supply the requirements of crop plants for an indefinite number of years, and yet the cost of materials supplying potassium reaches an enormous figure annually, it seems desirable to consider more carefully the possibility of increasing the availability of the potassium normally present in the soil. Since the problem is one which bears directly upon plant nutrition it was thought that more satisfactory results could be obtained by the growth and subsequent analysis of a plant possessing a high potassium requirement in an artificial soil of known composition, the potassium of which would be supplied in the form of one of the common minerals found in soils. By insuring the presence of other essential elements in available forms and in quantities sufficient to render potassium the limiting factor in the nutrition of the plant, such an investigation should give, in a measure, the availability of the potassium from the mineral supplying it, providing, of course, no serious detrimental factors should arise. In addition, it was thought that if certain other organic and inorganic substances would be added in such amounts as not to seriously interfere with the normal growth of the plant, their effect on the availability of the potassium might be noted.

It is clear, however, that such a method of investigation presents its own peculiar difficulties, such as lack of aeration, and the possible accumulation of substances harmful to plant growth due to the lack of drainage of the pots holding the artificial soil. Pots having drainage facilities would suffer a loss of soluble potassium not accounted for by plant analysis, and the same would hold true if the other plant nutrients were replaced from time to time. On the other hand, such an experiment should give comparative results, providing all factors influencing plant growth were controlled, to a greater or less degree, as was attempted in this investigation.

RESULTS OF PREVIOUS INVESTIGATIONS

It has been known for a long time that the ordinary potassium bearing silicates are measurably soluble in water.

This fact has been established as a result of experiments conducted by various investigators among whom may be mentioned the Roger brothers (38), Clarke (13, p. 156), Cushman (15), and Kahlenburg and Lincoln (29). In this connection Cameron and Bell (11, p. 17) declare that water brings about their hydrolysis as evidenced by the alkaline reaction obtained on treating an aqueous solution of the mineral with phenolphthalein. Recently Plummer (37) showed that the solvent action of carbonated water is very much greater than that of distilled water.

The liberation of potassium from its minerals has been accomplished in other ways, e.g., by the use of solutions of ordinary salts. Lemberg (30) and Beyer (7) have demonstrated that various salt solutions produced marked solubility effects on the potassium-bearing silicates.

The investigations cited, and similar experiments performed by André (3), Daubrée (17), Johnstone (28), and many others have established the fact that under certain conditions at

least, the potassium minerals are soluble in water, more so in carbonated water, and, if treated with solutions of certain inorganic compounds, their potassium may be replaced.

For a number of years, this problem of the liberation of soil potassium has been attacked in various ways. In 1848 Magnus (33) prepared an artificial soil to which he supplied potassium in the form of powdered feldspar only. With such a medium for plant growth, he was able to bring a crop of barley to complete maturity. Similar experiments were conducted by Aitkin (1), Nilson (34), Ballentine (4) and Feilitzen (22), showing that, under certain conditions, at least, part of the potassium of feldspar could be utilized by certain plants during their growth. Hartwell and Pember (26), however, as a result of extensive experimentation on the use of feldspar in this connection, came to the conclusion that little could be expected from this mineral as a source of available potassium for plant nutrition.

In 1860 Dietrich (18) conducted some experiments to determine the solubility of the soil constituents in various salt solutions. He found that potassium was more readily extracted from the soil by carbonated than by distilled water. Later, Dietrich (19) using 0.05 solutions of sodium chloride, calcium chloride, and calcium hydroxide, found that these solutions dissolved more potassium from soils than did pure water. He also found that solutions of sodium nitrate and sodium carbonate had no apparent effect upon the solubility of the soil potassium.

Fraps (23) claims that sodium sulfate, sodium nitrate or other salts have little effect upon the solubility of potassium in soils, but that lime or organic matter liberates this element to some extent. On the other hand, Lyon and Bizzell (32) place little emphasis on the effect of lime in the liberation of potassium from soils while Wheeler (41, p. 75), in summarizing certain experiments carried on at the Rhode Island Station, concluded that a study of the soils of that state did not justify the assumption that lime is to be considered as an extensive liberant of soil potassium.

PLAN OF THE EXPERIMENT

Description of the materials used

Pure white sand thoroughly leached with tap water and rinsed with distilled water was used throughout these experiments as a medium for plant growth. On analysis it was found to contain but a trace of potassium.

Orthoclase was chosen as the mineral to be used. In order to determine its maximum solubility in water under uniform physical conditions, it was pulverized to such a degree that it would readily pass through a 200-mesh sieve. Twenty-five-gram portions of the powder were transferred to Erlenmeyer flasks of 500 cc. capacity, each containing 250 cc. of distilled water and agitated on a shaking machine. It was found that the solutions contained 28.28 parts per million of potassium when equilibrium was obtained.

Buckwheat was chosen as the plant to be grown for two reasons, first, it is primarily a plant of high potassium requirement and, second, it grows reasonably well under greenhouse conditions.

The potassium content of high grade seeds similar to those planted was found equivalent to 1.16 per cent of their total weight, as determined by the method of Ames and Boltz (2, p. 206).

Earthenware jars were used in these investigations, a half-gallon and a gallon size, to each of which the same weight of sand was added.

The organic and inorganic substances used were chemically pure materials and were found to be practically free of potassium, with the exception of calcium carbonate which contained 1 mgm. of potassium in 25 gm. of the material. Dextrose and starch were chosen in preference to other organic additions mainly because of the fact that they are comparatively free of inorganic material.

A complete nutrient solution, in which the constituent compounds were dissolved and made up to volume separately, was devised. This was found to be acid to phenolphthalein

but alkaline to methyl orange. The weights of the different materials estimated on the water-free basis, the volume of distilled water added, and the amounts of each of the resulting solutions taken for one application are given in table 1.

Distilled water was added to the sand in the jars. Each jar was weighed daily and the water was maintained at a content approximating 14 per cent of the weight of sand. When the nutrient solution was added directly to the jars in the quantities indicated above, the resulting concentration at the optimum water-content of the sand was 36.3 p.p.m. of nitrogen, 51.5 of calcium, 32.7 of phosphorus, 41.7 of potassium, 31.6 of magnesium and a trace of iron.

Solutions of the sodium salts were made, having a volume of such concentration that 10 cc. corresponded to 41.7 p.p.m. of sodium when added to the jars. In like manner solutions of dextrose were made up, just before using, and in such concentration that 10 cc. were equivalent to 100 p.p.m. of this compound.

TABLE 1
Composition of nutrient solution

MATERIAL	AMOUNT	VOLUME	APPLICATION
	gm.	cc.	cc.
$(\text{NH}_4)_2\text{HPO}_4$	14.4908	8000	10
$\text{CaH}_4(\text{PO}_4)_2$	25.9389	8000	10
$\text{Ca}(\text{NO}_2)_2$	68.5225	8000	10
MgSO_4	99.7879	8000	10
K_2SO_4	9.1661	2500	10
FeCl_3	0.1000	250	1

EXPERIMENTAL

A preliminary experiment was undertaken in order to ascertain the practicability of this kind of investigational work. At the conclusion of this test, a more extended experiment was undertaken along the same lines. On May 26, 1919, the appropriate amounts of sand, alone and with the additions of the insoluble compounds, were weighed out and transferred to each of the 90 jars making nine different series of five duplicate tests each, as shown in table 2.

Fifteen grams of buckwheat were planted after the sand had been brought to its optimum water content. After the plants were well above the sand six uniform plants were selected for growth and the others removed with the exceptions of jars 18 and 20 in which seven plants were accidentally allowed to remain until they had reached such a state of growth that it was considered inadvisable to remove them.

The first application of the nutrients was made on June 2 followed by successive additions on June 9, 16, 23 and 30, and on July 7 and 13. The jars were weighed daily and brought to the optimum water-content, care being taken to prevent undue evaporation by white-washing the interior of the greenhouse roof and by keeping the floors sprinkled morning and afternoon.

On July 14 every plant was severed close to the sand, measured and then placed in a weighed tared envelope with the others of the same jar. After drying, the plants were analyzed, duplicate determinations being made instead of taking a composite sample of each individual treatment.

The data of this experiment are given in tables 3-6.

DISCUSSION OF RESULTS

A factor that affects the growth of plants either advantageously or disadvantageously is that of the reaction of the nutrient medium. In this connection attention is called to the fact that the complete nutrient solution used in this experiment was quite acid in reaction. In addition, it has been stated by Breazeale and LeClerc (9) that plants growing in the presence of compounds such as were used in this solution, render the solution more acid than originally through selective absorption.

While the effect of a nutrient solution moderately acid in reaction is that of hindering the elongations of root systems, this fact in no wise altered the

TABLE 2
Additions to the quartz sand medium in which plants were grown
Each pot contained 2750 gm. sand and other materials indicated

GENERAL TREATMENT	SUPPLEMENTAL TREATMENTS								
	Check	CaCO ₃ (25 gm.)	CaSO ₄ (25 gm.)	NaCl*	NaSO ₄ *	Dextrose† (0.2716 gm.)	Dextrose (0.2716 gm.) + CaCO ₃ (25 gm.)	Starch (0.2425 gm.)	Starch (0.2425 gm.) + CaCO ₃ (25 gm.)
	jar nos.	jar nos.	jar nos.	jar nos.	jar nos.	jar nos.	jar nos.	jar nos.	jar nos.
Complete nutrients.....	1-2	11-12	21-22	31-32	41-42	51-52	61-62	71-72	81-82
Complete less K.....	3-4	13-14	23-24	33-34	43-44	53-54	63-64	73-74	83-84
Same as 2 plus 25 gm. of ortho- clase.....	5-6	15-16	25-26	35-36	45-46	55-56	65-66	75-76	85-86
Same as 2 plus 50 gm. of ortho- clase.....	7-8	17-18	27-28	37-38	47-48	57-58	67-68	77-78	87-88
Same as 2 plus 75 gm. of ortho- clase.....	9-10	19-20	29-30	39-40	49-50	59-60	69-70	79-80	89-90

* Equivalent to a total of 0.1123 grams of sodium, one-seventh of this amount constituting one application.

† 0.2716 grams, one-seventh of this amount constituting one application.

ability of the plants of jars 1 and 2, which received the complete nutrients, to absorb the potassium supplied them in available form. These plants contained in their tops an average of 92 mgm. of the 112.3 mgm. of potassium supplied. From the data presented in tables 3, 4, 5 and 6 it seems that orthoclase must have exerted a beneficial effect on the nutrient solution as evidenced by yields and amounts of potassium absorbed by the plants of series 1. A greater amount of dry matter was obtained where 50 and 75 gm. of orthoclase were present than where the complete nutrients were supplied, notwithstanding the fact that less potassium was absorbed by the former plants.

TABLE 3
Total yield of dry material

JAR NOS.	GENERAL TREATMENT	SERIES 1—CHECK	SERIES 2—CaCO ₃	SERIES 3—CaSO ₄	SERIES 4—NaCl	SERIES 5—Na ₂ SO ₄	SERIES 6—DEXTROSE	SERIES 7—DEXTROSE + CaCO ₃	SERIES 8—STARCH	SERIES 9—STARCH + CaCO ₃
Ending in		gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.	gm.
1	Complete nutrients	4.20	4.31	4.08	3.59	4.21	3.86	5.24	3.76	2.55
2		4.33	4.50	5.05	3.89	3.14	4.22	4.39	3.86	3.51
3	Complete less K	0.99	1.31	1.52	1.14	0.57	1.06	1.81	0.58	1.35
4		1.13	1.40	1.37	1.02	1.07	0.90	2.18	0.47	0.63
5	Same plus 25 gm. orthoclase	3.23	4.36	3.84	4.25	3.68	2.29	2.98	1.92	3.27
6		3.58	3.83	4.00	4.23	3.24	2.61	2.17	2.36	2.81
7	Same plus 50 gm. orthoclase	4.36	4.24	5.05	4.65	4.19	3.81	3.38	3.19	4.02
8		4.77	4.88*	5.38	4.82	3.93	3.70	3.60	3.38	4.23
9	Same plus 75 gm. orthoclase	5.24	5.35	5.03	4.88	3.88	4.20	4.10	3.82	3.88
0		5.11	4.87*	4.44	4.30	3.81	4.06	4.08	3.24	3.93

* Seven plants.

TABLE 4
Total potassium absorbed

JAR NOS.	GENERAL TREATMENT	SERIES 1—CHECK	SERIES 2—CaCO ₃	SERIES 3—CaSO ₄	SERIES 4—NaCl	SERIES 5—Na ₂ SO ₄	SERIES 6—DEXTROSE	SERIES 7—DEXTROSE + CaCO ₃	SERIES 8—STARCH	SERIES 9—STARCH + CaCO ₃
Ending in		mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.	mgm.
1	Complete nutrients	89	92	97	91	97	94	106	100	90
2		95	94	111	102	98	102	111	96	106
3	Complete less K	7	8	10	10	8	11	14	8	14
4		10	9	10	8	9	9	18	7	8
5	Same plus 25 gm. orthoclase	24	39	36	36	27	17	23	19	25
6		32	38	35	33	17	22	19	19	22
7	Same plus 50 gm. orthoclase	54	52	65	57	36	32	31	40	44
8		57	61*	69	51	36	31	29	33	37
9	Same plus 75 gm. orthoclase	79	89	78	61	40	43	37	45	52
0		78	91*	74	55	35	43	37	45	43

* Seven plants.

As stated before very little potassium was present in the supplemental materials used, yet the plants of jars 3 and 4 were found to contain an average of 8.5 mgm. as shown in table 4. This absorbed potassium undoubtedly came

TABLE 5
*Average relative weights of dry material**

GENERAL TREATMENT	SERIES 1—CHECK	SERIES 2—CaCO ₃	SERIES 3—CaSO ₄	SERIES 4—NaCl	SERIES 5—Na ₂ SO ₄	SERIES 6—DEXTROSE	SERIES 7—DEXTROSE + CaCO ₃	SERIES 8—STARCH	SERIES 9—STARCH + CaCO ₃
Complete nutrients.....	100	103	107	87	86	95	112	89	71
Complete less K.....	25	31	34	25	19	22	46	12	23
Same as 2 plus 25 gm. of orthoclase.....	80	96	91	100	81	57	60	50	71
Same as 2 plus 50 gm. of orthoclase.....	107	107†	122	111	95	88	81	77	96
Same as 2 plus 75 gm. of orthoclase.....	121	120†	111	108	90	97	96	82	91

* The yield of plants receiving complete nutrients was taken as 100.

† Thirteen plants.

TABLE 6
*Average relative amounts of potassium absorbed**

GENERAL TREATMENT	SERIES 1—CHECK	SERIES 2—CaCO ₃	SERIES 3—CaSO ₄	SERIES 4—NaCl	SERIES 5—Na ₂ SO ₄	SERIES 6—DEXTROSE	SERIES 7—DEXTROSE + CaCO ₃	SERIES 8—STARCH	SERIES 9—STARCH + CaCO ₃
Complete nutrients.....	100	100	113	105	106	106	118	106	106
Complete less K.....	9	9	10	9	9	10	17	8	12
Same as 2 plus 25 gm. of orthoclase.....	30	42	38	37	16	21	22	20	25
Same as 2 plus 50 gm. of orthoclase.....	60	61†	72	58	39	34	32	39	44
Same as 2 plus 75 gm. of orthoclase.....	85	98†	82	63	40	46	40	49	51

* Plants receiving complete nutrients were taken as 100.

† Thirteen plants.

to a great extent from the jars themselves. Not more than 2.5 mgm. was present in the seeds. That this amount represents closely the quantity set free in the other jars as well is indicated by the amount of potassium absorbed by the plants of series 1 grown in the presence of varying amounts of orthoclase. Taking the blanks into consideration it would appear that the tendency of the plants was to absorb a quantity of potassium directly proportional to the amount of mineral added.

EFFECT OF CALCIUM SALTS

The effect of calcium carbonate on the absorption of potassium from orthoclase is shown by the plants of series 2, tables 3 and 4. The average amount of potassium taken up by the plants receiving the complete nutrients in addition to calcium carbonate, i.e., those of jars 11 and 12 was approximately the same as in the absence of the lime salt.

The check plants of this series receiving the potassium-free nutrient solution in addition to calcium carbonate, as compared with those of series 1, showed that no more potassium was absorbed than in the absence of the latter addition. On subtraction of this blank, however, it is evident that more potassium was taken up by the plants from orthoclase in the presence of carbonate of lime. The plants of jars 15 and 16 absorbed an average of 30 mgm. of potassium from the mineral or 10.5 mgm. more than the plants of jars 5 and 6. Where increasing amounts of orthoclase were used in addition to the calcium carbonate treatment, the increased absorption of potassium was almost in direct proportion to the amount of mineral added, and in all probability would have been more nearly so if the extra root system of the additional plants in jars 18 and 20 were taken into consideration.

The reason for the better growth of the plants of this series may be partly due to calcium functioning as a plant nutrient but in all probability most of its effect can be attributed to its neutralizing action on the acidity of the nutrient medium, thereby rendering a more favorable condition for plant growth. In series 1 and 2 it is noted that the increasing growth obtained where orthoclase was present was also accompanied by an increase in the amount of potassium absorbed. In both series, however, greater growth was obtained where orthoclase was present notwithstanding the fact that more potassium was taken up from the complete nutrients. In all probability, the increased absorption of potassium was due primarily to the greater growth of the plants, inasmuch as plants grown under favorable conditions should have a greater feeding capacity than plants grown under conditions less favorable.

That plants grown under favorable conditions would absorb more potassium from orthoclase than those grown in an unsatisfactory medium is evident from results obtained by investigations conducted by Cushman and Hubbard (16), Van Bemmelen (6), DeTurk (21), Beaumont (5, p. 17), and others. Their experiments indicate that very little of the potassium obtained on the hydrolysis of a feldspar goes directly into solution but rather it is held in the colloidal covering of hydrated aluminum silicate surrounding each particle in the form of an absorption compound. Assuming then, that each particle of orthoclase becomes covered with colloidal matter, such a film, according to Beaumont (5), will bring into solution a certain amount of potassium, and under certain conditions this is a fairly constant quantity. If, however, plant roots come into contact with such a film, part of the potassium will be removed and the equilibrium destroyed. The tendency, therefore, would be for more potas-

sium to be made available from the mineral and to replace the amount removed by the plant. If this is true, it would appear that the amount of potassium absorbed from orthoclase depends upon the extent of root development and the greater the development the more of the element absorbed. Such a condition naturally arises where the medium is more favorable for plant growth.

There is a marked distinction between the relative availability of the potassium when supplied as the sulfate or mineral. A study of the plants of the different series as shown in table 4 reveals the fact that all plants receiving the complete nutrients with or without other supplementary treatments absorbed practically all of the potassium, and that this element was taken up regardless of the general character of the plants themselves. This fact indicates that water-soluble potassium can be taken quantitatively from a sandy medium and that the amount absorbed is not dependent upon the relative extent of root development. A further study of these particular plants shows, that those of inferior growth contained relatively more potassium in their tops than those more normal in character. In all probability, where the conditions were less suitable for maximum development those plants had a less extensive root growth and consequently less potassium would be found in the roots and more in the tops. These facts show that if potassium goes directly into solution it may be taken up by plants regardless of their general character and this would hold true for the potassium of orthoclase as well as the sulfate. If no interfering factors were present all the plants grown in the presence of varying amounts of orthoclase would absorb relative quantities of potassium and, if the solubility of this element was affected by certain additions, then the amount of potassium absorbed would indicate the relative efficiency of the various additions in this connection. As such results were not obtained it is clear that certain other factors interfered and in all likelihood one was the colloidal matter of the partly hydrolyzed orthoclase.

The plants of jars 21 and 22 receiving the complete nutrients plus 25 gm. of calcium sulfate are shown to have more potassium in their tops than those receiving the complete nutrients alone or with calcium carbonate. This is probably due to a less developed root system and the excess potassium, instead of being utilized for such growth in the connection, is taken up by the main portion of the plants. Plants absorb more of the essential elements than they ordinarily require and at the same time they manifest a selective absorption in regard to certain radicals. The tendency of a nutrient solution containing calcium sulfate when used for plant growth is to become more acid in reaction due to the fact that calcium is more readily absorbed than the sulfate radical. Pitz (36) has found that small amounts of calcium sulfate greatly increased the extent of root systems but for some reason larger concentration had the opposite effect. While the solubility of calcium sulfate is quite low in distilled water, potassium sulfate, according to Cameron and Bell (12, p. 9) increases its solubility to a great extent. This would result in

more calcium being absorbed and the acidity of the nutrient medium to increase with the possibility of such an increase in acidity being great enough to interfere with normal plant growth.

The plants of this particular series show that those of jars 25 and 26 absorbed more potassium from 25 gm. of orthoclase than was absorbed from the same amount of the mineral through any other treatment. Those of jars 27 and 28 not only absorbed more potassium from 50 gm. of orthoclase than with any other treatment, but gave the highest yield of dry matter of the entire experiment as shown in tables 5 and 6. The nutrient medium in this particular instance must have been of optimum reaction and concentration.

Those plants of jars 29 and 30 grown in the presence of 75 gm. of orthoclase, however, gave a lower yield of dry matter than the plants just mentioned and relatively less potassium was absorbed, undoubtedly because the feeding powers of the plant were impaired to the same extent and by the same causes as stated for the case of the plants of jars 21 and 22; or the action may have been due to an accumulation of dissolved calcium sulfate.

It is evident that under certain conditions calcium sulfate aids in the absorption of potassium from orthoclase but that increased absorption is probably due to the increased growth of the plants under these conditions rather than direct replacement of potassium by calcium from the mineral. This statement is in keeping with those of Hart and Tottingham (25), and Pitz (36). That calcium sulfate under other conditions is somewhat injurious to plants has been proved by Fraps (23), and that calcium sulfate in solution does not liberate potassium directly is indicated by the results obtained in experiments conducted by Briggs and Breazeale (10).

EFFECT OF SODIUM SALTS

As shown in table 6 those plants of series 4 receiving sodium chloride plus the complete and potassium-free nutrients contained the same amount of potassium as was taken up by those plants grown in the absence of this salt. Where 25 gm. of orthoclase were present, however, better growth was obtained and more potassium was absorbed than in the similarly treated plants of series 1 where sodium chloride was absent. This indicates in a measure at least, that where potassium is present in limited quantities this salt may serve as a substitute, increasing the growth of the plants and indirectly causing an increased absorption of potassium from the mineral.

The plants growing in the presence of 50 gm. of orthoclase and sodium chloride were approximately the same, both in yield and the amount of potassium absorbed, as those grown in the absence of this salt.

This was not true, however, of the plants of this series grown in the presence of 75 gm. of orthoclase, as both the yield and the amount of potassium absorbed were decreased by the sodium chloride.

The effect of sodium sulfate was found to be less satisfactory in comparison with sodium chloride. It must be remembered, however, that relatively

greater amounts of this salt was used than the chloride and it is fairly well known, according to different experiments conducted by Hart and Tottingham (25), Fraps (23) and Breazeale (8) that this salt sometimes has an injurious effect on plants. In some instances this harmful action has been ascribed to the concentrations of the medium rather than to an increase in the hydrogen-ion concentration which might arise through selective absorption by the plants themselves.

EFFECT OF ORGANIC MATTER WITH OR WITHOUT CALCIUM CARBONATE

Application of dextrose seriously interfered with the growth and potassium absorption of the plants of series 6 as shown by tables 5 and 6. That such an effect is not altogether unusual has been proved by Lipman and others (31). They found that dextrose applied in a somewhat similar manner depressed the yield of plants.

The too rapid evolution of carbon dioxide, one of the products formed in the decomposition of dextrose, tends to drive out the oxygen from the nutrient solution. According to Snow (39), lack of oxygen seriously interferes with root-hair development of plants, thereby decreasing its absorption powers to some extent. Noyes and Weghorst (35) are of the opinion that carbon dioxide is detrimental to root growth and in fact De Saussure (20) as early as 1804, found that plants grown in pure carbonated water were injured to a considerable extent.

Other acids are also found as decomposition products of dextrose and it was thought that applications of calcium carbonate would tend to neutralize them and so prevent an unsuitable reaction of the nutrient medium. As a matter of fact, such additions failed to exert a pronounced beneficial effect on either the growth of the plants or the amount of potassium absorbed as shown by the data of tables 5 and 6, series 7.

The reasons for these results may be an accumulation of soluble calcium compounds formed by the reaction of calcium with the products of organic decomposition or, perhaps, as the calcium was made available sufficient quantities were absorbed by the plants to seriously interfere with their normal activities. In the latter connection Clevenger (14) found that the hydrogen-ion concentration of the sap of buckwheat plants was lessened in every instance where lime was supplied to the nutrient medium. It is perfectly obvious that a lowering of the concentration of hydrogen-ion would result in affecting the general well being of plants.

Truog (40) found that additions of lime to acid soils sometimes retarded the growth of crops immediately following, such as oats, wheat and corn, which have low lime requirements. He says, however, that this is due to temporary conditions which soon disappear and the lime then greatly benefits these crops as well as those with high lime requirements.

The data concerning the plants of series 8 as shown in tables 4 and 5 indicate that the deleterious effect of starch when used alone on plant growth is more

pronounced than those of dextrose. It is shown, however, where calcium carbonate was used with starch that in a measure at least, the yields and the amounts of potassium absorbed were increased.

From the result of the experiment it is impossible to say whether or not organic matter liberates potassium from orthoclase, as the use of organic substances under the conditions of this experiment shows that such substances seriously interfere with plant growth and thereby obscure their effect on the mineral itself.

SUMMARY AND CONCLUSIONS

This investigation had for its purpose the testing of the rate of availability of the potassium of orthoclase when supplied in finely divided form to buckwheat grown in quartz sand cultures.

Twenty-five-gram portions of the orthoclase, pulverized to pass through a 200-mesh sieve, when subjected to the solvent action of distilled water were found to yield soluble potassium at the rate of 282.2 parts per million at the point of equilibrium between solute and solvent. This was equivalent to 7 mgm. of potassium.

This orthoclase was added in 25-, 50- and 75-gram portions and intimately mixed with 2750 gm. of sand to which the other necessary plant nutrients had been added in available forms.

Availability of the potassium of the orthoclase was estimated from the dry weights of the buckwheat plants and from the amounts of the element absorbed by them when the orthoclase was the only source of potassium as compared to the results secured from the use of water-soluble potassium.

The effects of supplemental additions of calcium carbonate and sulfate, of sodium chloride and sulfate and of glucose and starch on the rate of availability of the potassium of the orthoclase measured as indicated above were also studied.

As a result of these studies the following conclusions seem justified:

1. Fifty-gram portions of orthoclase supplied potassium at a sufficiently rapid rate to satisfy the requirements of 7 per cent larger yields of dry matter than were produced by the complete nutrient solution. With 75 gm. of orthoclase the dry weights of plants were 21 per cent greater than those produced by the use of the complete nutrient solution.

2. The plants grown in pots in which the potassium was supplied as orthoclase contained only 30, 60 and 85 per cent as much potassium for the 25-, 50- and 75-gram portions of orthoclase, respectively, as were contained in the plants grown in the complete nutrient solution.

3. The total amount of potassium available from the orthoclase was in no case as large as that in the nutrient solution but the physiological balance of the solution in the sand culture was apparently favorable to a more economical use of the element.

4. Calcium carbonate and sulfate tended to increase the quantity of available potassium. They also aided in the production of a larger amount of dry matter as long as the lack of potassium was a limiting factor in the growth of the plants.

5. When the lack of available potassium was a limiting factor sodium chloride tended to increase the weights of dry matter but on the whole reduced the amount of available potassium. The effect of sodium sulfate was negative both as to weight of dry matter and amount of potassium absorbed.

6. Dextrose and starch tended to reduce the weight of dry matter and of potassium absorbed. The addition of calcium carbonate to these materials did not materially affect the results with dextrose but resulted both in an increase in yield and of potassium absorbed with starch.

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AUTOBIOGRAPHY

I, Dennis Edward Haley, was born near Wilmington, Ohio, July 22, 1885. Practically all of secondary school education was received in the public schools of Clinton County, Ohio, and my undergraduate education at the Ohio State University, from which the degree of Bachelor of Science in Agriculture was obtained in 1913. Graduate work was pursued at the Ohio State University and The Pennsylvania State College, the degree of Master of Science being obtained from the latter institution, in 1916. Since 1914, I have served as Instructor, Assistant Professor and Associate Professor in the Department of Agricultural Chemistry at The Pennsylvania State College. I spent the college year 1918-1919, the following summer, and the summer of 1920 in further graduate work at the Ohio State University and in 1919, I was elected a member of the Sigma Xi. In 1921, together with Dr. J. G. Lyman, I published an article entitled "Castor Bean Lipase: Its Preparation and Some of Its Properties." In 1922, I received from the Ohio State University the degree of Doctor of Philosophy.

